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BANK DEBT AND PUBLICLY TRADED DEBT IN REPEATED OLIGOPOLIES

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Bank Debt and Publicly Traded Debt in Repeated Oligopolies

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Abstract

This paper investigates the link between collusion on product markets and the role of bank financing. The value of a levered firm in a cartel can be increased if debt is repaid as fast as possible. If demand is uncertain, then bank debt can attain the fastest repayment path by renegotiating the debt service to the actual demand state, while public debt is constrained to a slower pay-down. Bank-financed industries can sustain more collusion and a higher debt capacity. Industry characteristics explain the choice between public and bank debt: Firms in industries with little demand volatility, competitive market conduct and a high degree of market concentration will prefer cheaper publicly placed debt. Collusion on product markets can explain a prominent role of bank financing, while collusion on financial markets has the opposite effect. The dynamic evolution of mixed debt structures is explained, with private debt being paid down faster than public debt.

Keywords: Finance and product markets, collusion, private and public debt, limited liability effect, debt renegotiation.

JEL Classification: G21, G32, L13.
1. Introduction

The interaction between capital structure and product market behavior has spurred theoretical and empirical research efforts for some time. Most of this research has focused on the choice between debt and equity and has remained agnostic about the institutional form of debt. This paper explores the question whether the choice of the debt structure, and in particular the choice between intermediated debt and directly placed (public) debt, should matter for the intensity of industrial competition, and vice versa.

A first motivation behind this question is to understand the capital structure choice of firms who are concerned how their financing may affect the product market environment. Consider a firm that plans a discrete increase in its debt financing, say because it undergoes a leveraged transaction (like a LBO) in order to increase its value. By sending a signal of increased competition to other firms, levering up may be strategically harmful to the objective of increasing value. How to structure the financial package so as to minimize the ensuing competitive pressure? This paper looks at this question in the repeated games model, the leading candidate to analyze industry collusion.

A second motivation stems from the comparison of bank-oriented and market-oriented financial systems. Continental Europe and Japan relied traditionally almost exclusively on bank debt, while corporate bonds played a significant role in the United Kingdom and in the United States. Recent research in comparing these financial systems shows some indication of a relationship between industry structure and financial systems. Rajan and Zingales (1998) and Demirguc-Kunt and Maksimovic (1996) present evidence, based on microeconomic data, that differences in financial systems can account for variations in growth rates and research intensities across industry sectors. In the theoretical model of Perotti and von Thadden (1997), bank-oriented financial systems will promote industries where firms find it advantageous to keep information about demand or capacity from their competitors. Economic historians have long argued that in late-developing countries, there has been an intimate relationship between the development of capital-intensive industries and the emergence of bank-oriented financial systems. For example, Alexander Gerschenkron argued that, with respect to Continental Europe and particularly Germany in the late 19th century, banks were actively involved in the shaping of industries and the tendency towards cartelization and collusion. "The momentum shown by the cartelization movement of German industry cannot be fully explained, except as the natural result of the amalgamation of German banks. ... The banks refused to tolerate fratricidal struggles among their children" (1962, 15).
In spite of the venerable tradition in suspecting a link between collusion and bank financing, this relationship has never been the subject of a formal theoretical analysis, a gap which this paper attempts to fill.

The model is set up to follow closely earlier work on the interaction of capital structure and product market behavior. Probably the most influential result in this literature refers to the "limited liability effect" and predicts that indebted firms will behave more competitively. This has been explored in the seminal paper by Brander and Lewis (1986).¹ Limited liability will make leveraged firms more eager to take risks. A sufficient condition for this prediction is then the assumption that a more competitive behavior is associated with an increase in risk. Maksimovic (1988) has investigated the limited liability effect in the context of repeated oligopolies. He shows that collusion is harder to sustain because debt limits the possible punishments that can be inflicted on a deviant.

The purpose of this paper is to extend the framework of Maksimovic' model to allow for a choice between bank debt and publicly traded debt. Specifically, the paper explores the following problems: how do different debt choices influence the highest sustainable level of collusion in an industry? And what are the consequences for the choice between public and private debt? The difference between bank debt and publicly traded debt is that bank debt can be made state-contingent while public debt cannot, or at least to a much lesser extent. State contingency means that, upon arrival of new information, bank debt can be rescheduled, called early or be increased. This view is inspired by recent literature on the choice between private and public debt which appears to agree on this point.²

The present paper allows for a richer class of debt contracts compared to Maksimovic (1988). Maksimovic assumes that loans are non-monitored and non-renegotiable - they amount to public debt contracts, in the terminology of the current paper. Moreover, he confines attention to stationary debt contracts; however, stationary contracts are not optimal because an accelerated pay down alleviates the underlying problem of constrained collusion. Consequently, in the present paper, the debt repayment path is intertemporally optimized, and bank debt is monitored and renegotiable.

¹A variant with strategic bankruptcy is to be found in Brander and Lewis (1988). Levering up may be used as a commitment to an aggressive output market strategy, and Fulghieri and Nagarajan (1992) show conditions for such a commitment to be renegotiation-proof. For an excellent survey, see Maksimovic (1995).

²This is true for the two preeminent lines of this research, the papers emphasizing monitoring services of banks (including Diamond (1991), Rajan (1992), Chemmanur and Fulghieri (1994) and Repullo and Suarez (1998)) as well as those deriving state-contingency from the principle that bank debt can be more efficiently renegotiated than public debt (Bolton and Scharfstein (1996), Bolton and Freixas (1994) and Detragiache (1994)).
The paper has the following main results. The starting point is the observation that the faster debt is repaid, the more collusion can be sustained later on. As a consequence, if firms maximize collusion, all of the gross profits should initially be distributed to the creditors. This is the fastest repayment path. Now suppose that industry demand is fluctuating as in Rotemberg and Saloner (1986). Then the fastest repayment path can only be attained by renegotiating debt after the demand state is known: Failure to adjust the debt repayment to the sustainable level leads to financial distress. Thus, if firms have renegotiable debt, they can sustain maximal collusion, but if debt is non-renegotiable, debt services have to be so low as to avoid excessive costs of financial distress - which is bad news for collusion. The choice between public and private debt is explained based on the following industry characteristics: Firms in industries with stable demand, a relatively competitive market conduct or a high market concentration should prefer public debt, while firms on volatile markets with a highly collusive conduct and low industry concentration should prefer private debt. Moreover, the more shocks to the industry demand are expected to be permanent (market booms or slumps), the higher the value of bank debt. In short, the more fragile the conditions explaining the sustainability of collusion, the higher should firms value the state-contingency of bank debt.

Thus, collusion on product markets appears to favor the use of bank debt. Concerning collusion on financial markets, however, the effect is reversed: the more collusive credit markets are, the less bank financing will be used because obtaining direct financing at competitive rates becomes then relatively more attractive. Thus, the conjecture about the relationship between collusion and bank financing must be differentiated according to the sector where collusion is thought to be pervasive.

In addition, bank credit allows for a higher debt capacity. The paper explains mixed debt structures as optimal combinations of cheaper publicly floated debt and more flexible private debt. The optimal debt repayment path leads to de-leveraging, and state-contingent debt will be paid down faster than non-renegotiable debt.

With regard to the established theory of repeated games, this paper contains two noteworthy innovations, namely the inclusion of non-stationary contracts and the renegotiation of financial contracts. The results show that contract renegotiation and non-stationarity are intertwined: if debt can be renegotiated, then the fastest repayment path will lower at some point to a level where collusion is unconstrained. Without renegotiation, the constraint on collusion may be permanent even under the optimal contract. Moreover, the analysis of renegotiation allows for an interesting perspective on the strategic role of third
parties (industry competitors) in debt restructurings. In the present model, collusion is two-edged: Firms collude not only against their customers but also against their financiers by jointly imposing the terms of renegotiation, and the strategic impact of competitors upsets the bargaining power relation between creditor and borrower.

Stenbacka (1994) is the only earlier paper on repeated oligopolies with debt besides Mak-simovic (1988). He emphasizes the trade-off between the limited liability effect and the tax shield of debt. A few other papers have looked at the interaction between bank credit and industrial competition. Three recent papers emphasize the role of financial intermediaries in the exchange of information between competitors or in keeping information from leaking out in public, respectively. In Bhattacharya and Chiesa (1995), banks are inside investors which organize an efficient exchange of information in a patent race. In the papers by Yosha (1995) and Perotti and von Thadden (1997), private debt can help to conceal information which would inevitably leak out to competitors in the process of a public debt placement. Poitevin (1989) explores the impact of a common investor in the Brander and Lewis model. A bank financing several firms in an industry will internalize the side effects of its lending decisions and therefore induce a less competitive industry equilibrium. The present paper has no direct relationship with any of these papers: Information exchange or a common financier play no role.

The paper is organized as follows. The model is presented in Section 2. The two debt alternatives are then introduced separately: In Section 3, the bank debt equilibrium and the fastest repayment path, in Section 4 the public debt equilibrium. Section 5 collects the elements for a comparison of firm values and debt capacities. Various industry characteristics explaining the choice between public and private debt are introduced in Section 6. Collusion among banks is discussed in Section 7. Callable debt and bridge loans are considered in Section 8. In Section 9, empirical implications are presented, and Section 10 concludes.

2. The Model

The model depicts \( n \) identical entrepreneurs in an industry facing two sources of credit: public debt and bank debt. To stay in the industry, each entrepreneur has to raise funds in the amount of \( I \) from bondholders or a bank. Entrepreneurs and creditors are risk-neutral and face identical outside options with discount factor \( \delta \).

Suppose all \( n \) firms have successfully raised capital. The stage game \( G \) is a standard
Bertrand game.\(^3\) \(G\) is repeated infinitely. The game is perfectly symmetric, and I restrict attention to symmetric outcomes (except for deviations). Profits fluctuate over time according to unpredictable demand shocks, indicated by the state variable \(\theta_t\). Let \(\theta_t\) be a random variable with support \([\underline{\theta}, \bar{\theta}]\) which is independently and identically distributed (relaxed in Section 6) and has cumulative distribution function \(F(\theta)\). The only restriction imposed on \(F(\theta)\) is implicitly contained in Assumption 4 below. The symbol \(\pi\) is used for profit per firm and \(\pi^M(\theta)\) denotes the per-firm profit under joint profit maximization. I assume that \(\pi^M(\theta)\) is strictly increasing in \(\theta\), so \(\pi^M(\bar{\theta})\) denotes the upper and \(\pi^M(\theta) > 0\) the lower bound of possible state-contingent profit if firm jointly maximize profits and the industry is an all-equity industry. Note that in a Bertrand game, the stage game payoff under Nash-reversion is equal to zero. Thus, any \(\pi\) such that \(0 < \pi \leq \pi^M(\theta)\) indicates that some sort of collusion takes place. If \(\pi\) is the per firm profit targeted by colluding firm in a given period, then \(\pi \cdot \pi_t\) measures the maximal profit of a firm deviating from the collusive play in \(t\) because in the Bertrand game the deviator can undercut the competitors just by a tiny fraction and come arbitrarily close to reaping the entire profit in the industry. Each firm can cease production at no cost. Hence the maximum punishment implies a zero continuation payoff which, under Bertrand competition, can be established by a trigger strategy (Nash reversion) as well as by other punishment regimes (like Abreu's (1988) simple punishment profile). Let \(V(.)\) represent the per-firm present value of expected future profits in period \(t\). Specifically, let \(V^M_t = \frac{1}{1-\delta} E \pi^M(\theta)\) be the present value of profits under stationary joint profit maximization (where expectations are taken with respect to \(\theta\)).

I assume that, due to perfect competition on the two credit markets, creditors will earn zero expected profit. This is a useful benchmark; I will relax this assumption and consider collusion among banks in Section 7. Neither banks nor the market for public debt face quantity constraints on the loans they can offer. All debt repayments are made out of current profits, so entrepreneurs cannot be induced to use retained earnings from the past to meet current debt obligations.\(^4\) The hypotheses guiding debt contracts and contract renegotiation are summarized by the following three assumptions.

**Assumption 1:** Only standard debt contracts are feasible (payments to investors can only

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\(^3\)The restriction to Bertrand competition is for simplicity only. For the present discussion, industrial competition matters only via its impact on the deviation profit. A sufficient condition for the results to hold qualitatively is that the net gain of a deviator is an increasing function of the profit obtained by sticking to the collusive agreement. This condition is true for a large class of models, including standard Cournot models.

\(^4\)Even if entrepreneurs can save, it is hard to induce them to give the savings up to meet debt obligations, for the same reasons as those exposed in Section 8 about voluntary debt retirements (callable debt).
depend on time). Contracts can only be signed initially.

This assumption contains two elements. First, equity financing is ruled out issues which would dominate debt in the present model. This assumption should be put in the following perspective: The literature suggests a number of reasons why debt issues are preferable to equity, and we observe that debt financing is of overwhelming importance in practice. Therefore, the paper takes the motives to issue debt for granted and asks for the optimal debt structure.

Second, the exclusion of recontracting is primarily motivated by the transaction costs of issuing debt. Costs of issuing debt are considerably lower for bank debt compared to public debt. Also, the public debt positions of companies’ are usually relatively stable in the short run. Therefore, the present model stipulates that continuously re-issuing of corporate bonds would be a fairly inefficient way to obtain state-contingent claims. In Section 8, I come back to this point.

With this assumption, a financial contract is fully specified by a payment plan which depends only on time and which is denoted by \( (d_t)_{t=0}^{\infty} \) where \( d_t \) is the contractual payment in period \( t \).

**ASSUMPTION 2:** A firm which defaults on its current debt obligation cannot be induced to sustain collusion in that period. The firm enters the next period with no change in its capital structure.

Assumption 2 stipulates that collusive profits are foregone for one period as a consequence of a default. These introduces endogenous bankruptcy costs in a way which is directly related to the repeated game. Namely, this assumption could be generated by the following explicit extension of the game: Suppose that after a default, the firm is sold in an auction and the proceeds are distributed among creditors and shareholders according to the priority of their claims. The incumbent entrepreneur is replaced by a new owner-manager with a sufficiently high probability to explain that there is no collusion in the default period.

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5The most prominent theoretical foundation for standard debt contracts has been contributed by the costly state verification literature, see Townsend (1979) and Gale and Hellwig (1985).

6The importance of transaction costs in public debt issues is documented in Barclay and Smith (1995).

7In fact, in the current model, the firm is worth more than the debt claims if collusion continues to be sustained so equityholders end up with a positive value.

8Because replacement is anticipated, the threat of future punishment will not keep the incumbent entrepreneur from deviating, and as a consequence, the industry reverts to the competitive outcome for (at least) one period. A probability of more than \( \frac{1}{n} \) is sufficient.
In addition, the assumption stipulates that the capital structure is unaffected by bankruptcy. This appears as the most neutral assumption because capital structure affects the highest possible firm values in this model. The main results of this paper do not depend on this assumption, i.e. they go through whether bankruptcy leads to an increase or a reduction in leverage (which is inversely related to possible firm values).\(^9\)

Finally, I add an assumption explaining the difference between the two forms of debt. The following assumption formalizes the idea that only bank debt can be made state-contingent:

**Assumption 3:** Banks build a relationship with the firm and incur a fixed up-front cost of \(M\). Banks and entrepreneurs can observe the state \(\theta_t\) at the beginning of each period. Bank debt can be renegotiated without any additional cost. After observing \(\theta_t\), the bank can make a take-it-or-leave-it offer to the entrepreneur, proposing to exchange for a new debt contract. By contrast, public creditors cannot observe \(\theta_t\) and cannot renegotiate their debt contracts.

This assumption is inspired by the literature showing that debt renegotiation becomes more difficult with a large number of creditors or a complex debt structure.\(^{10}\) Also, state-contingency of bank debt requires that the bank be informed about the industry conditions and is therefore costly. The functional form of monitoring costs can be relaxed, as I examine in Section 7.

---

\(\theta_t\) banks make offers to entrepreneurs. \(\pi_t(\theta)\) are renegotiation offers. If \(\pi_t < d_t\), the entrepreneur accepts or rejects the offer. If accepted, \(d_t\) due. If rejected, default.

**Figure 1: Timing in the stage game**

The timing is as follows. After initial contracts have been signed, the first stage of the repeated game comes up. In every single stage of the repeated game, entrepreneurs move

\(^9\)With an increase in leverage, there is an additional bankruptcy cost and the results hold a fortiori. For the converse part, see zzz [first version of the current paper].

\(^{10}\)There is empirical evidence that out-of-court debt restructurings are more likely to succeed if large private creditors are involved, for example in Gilson, John and Lang (1990) or Asquith, Gertner and Scharfstein (1994).
simultaneously and investors move simultaneously. The timing of the stage game in the repeated game is summarized in Figure 1. (where renegotiation is absent under a public debt contract.)

The equilibrium concept is Perfect Bayesian Equilibrium, ensuring that the play is an equilibrium in every possible continuation game and that players use rational beliefs about the $\theta_t$-process.

In repeated games, there is normally a multitude of equilibria which differ in the degree of collusion. A convenient measure of collusion in this model is $V_0(\cdot)$, the initial per firm-present value of expected profits. For the moment, I focus exclusively on equilibrium profiles where $V_0(\cdot)$ is maximized (collusion is highest) as the benchmark, because this gives rise to the most clear-cut comparison of bank and public debt. In Section 6, I extend the analysis to the whole range of industries with a more or less competitive market conduct.

It is instructive to start the analysis by considering how debt alters the incentive constraints ensuring that firms do not want to deviate. As a useful benchmark, consider the incentive constraint at time $t$ for an all-equity industry which assures that no firm wants to deviate:

$$n \cdot \pi_t(\theta_t) \leq \pi_t(\theta_t) + E \sum_{\tau=1}^{\infty} \delta^\tau \pi_{t+\tau}(\theta_{t+\tau}) \quad \forall t \geq 0$$

(1)

This incentive constraint relates the current net gain from a deviation $n \cdot \pi_t(\theta_t)$ to the present value of all future profits accruing to the manager. For leveraged oligopolies, debt payments have to be deducted on both sides of the equation:

$$n \cdot \pi(\theta_t, D_t) - d_t \leq \pi(\theta_t, D_t) - d_t + E \sum_{\tau=1}^{\infty} \delta^\tau \pi_{t+\tau}(\theta_{t+\tau}, D_{t+\tau}) - \delta D_{t+1} \quad \forall t \geq 0$$

(2)

Thus, debt is entering the incentive constraint with two unequal terms: only the current debt service is subtracted from the current deviation gain (left-hand side), while the entire present value of debt outstanding is important for the expected present value from compliance (right-hand side). On the one hand, adding debt makes this constraint harder to meet. Reducing the current profit, on the other hand, adds slack to this constraint because the reduction enters the LHS profit multiplied by a factor of $n$. This is how leverage puts a limit on sustainable collusion.

A symmetric payoff $\pi_t$ is called sustainable under the repayment path $(d_\tau)_{\tau=t}^{\infty}$ if there is a (Perfect Bayesian) punishment profile deterring any deviation from the strategies supporting $\pi_t$. 

8
3. The bank equilibrium and the fastest repayment path

For analytical convenience, attention is confined in this and the next section to industries where all firms are either bank-financed or publicly financed. Section 5 and 6 compare the two and Section 7 discusses mixed debt structures.

The value-maximizing equilibrium is the solution to a stochastic dynamic optimization problem which determines simultaneously the value-maximizing path of debt repayments and a value-maximizing path of profits. In principle, every possible history of the \( \theta_t \)-process including the current realization is a state in this optimization problem. Thanks to the stationarity of the problem, however, it is easy to see that the optimal path is history-dependent only as far as the remaining debt level \( D_t \) is concerned. Thus, the relevant state can be conveniently summarized by the pair \((\theta_t, D_t)\).

The superscript \( B \) denotes the bank equilibrium. I denote the optimal repayment path by \( d^B_t(\theta_t, D_t) \) and the optimal profit path by \( \pi^B_t(\theta_t, D_t) \), for \( t = 0, 1, \ldots, t \). That is, \( \pi^B_t(\theta_t, D_t) \) is the highest sustainable collusive profit in \( t \), given that \( \theta_t \) has been realized, and given that all agents expect repayments \( d^B_t(\cdot) \) to be sequentially implemented. Finally, \( V^B(D_t) = E \sum_{\tau=0}^{\infty} \delta^\tau \pi^B_{t+\tau}(\theta_{t+\tau}, D_{t+\tau}) \) is the present value of the value-maximizing equilibrium with bank debt.

From the recursive structure of the stochastic programming problem, it follows that the continuation path \((\pi^B_{\tau}(\cdot))_{\tau=t}^{\infty} \) maximizes the present value of profits after any history:

\[
V^B(D_t) = \sup \left\{ E \sum_{\tau=0}^{\infty} \delta^\tau \pi^B_{t+\tau}(\theta_{t+\tau}, D_{t+\tau}) \right\} \\
\text{s.t.} \quad \pi^B_{t+\tau}(\theta_{t+\tau}, D_{t+\tau}) \text{ is sustainable } \forall \tau > 0 \tag{3}
\text{and} \quad E \sum_{t=0}^{\infty} \delta^t d_t(\theta_t, D_t) = 1
\]

The first constraint requires incentive compatibility everywhere. The second constraint expresses individual rationality of the lenders who must expect to break even.

Before solving this problem, I first verify that the optimal path of the debt values \( D_{t+1} \) is deterministic and depends only on time. A sufficient condition for this is the following property of the curvature of the value function:

**Lemma 1**: \( V^B(D_t) \) is strictly concave in \( D_t \).

**Proof**: See the Appendix.

This concavity implies that is not optimal to alter the debt level \( D_t \) over time. Therefore, I can restrict attention to the following equilibrium construction (not necessarily the unique
value-maximizing equilibrium): Only the current debt service is altered in renegotiation. The present value of future debt claims is unaffected by renegotiation. As a consequence, bank debt is risky because the total value of repayments is determined along the way and depends on the actual history of the \( \theta_t \)-process unfolds. Conveniently, the notation for the state-contingent variables can then be abbreviated as \( \pi^B_t(\theta_t) \) (maximal profit) and \( d^B_t(\theta_t) \) (optimal repayment) because the remaining debt level \( D_t \) is fully explained by the time index.

As a consequence of keeping future debt values deterministic, bank debt is risky because the total value of repayments is determined along the way and depends on the actual history of the \( \theta_t \)-process.

In order to solve problem (3), suppose for the moment that there is total flexibility in making debt repayments state-contingent. This assumption will be verified in Proposition 1. Fortunately for our purposes, it turns then out that the problem (3) can only have a boundary solution. The next Lemma establishes this key insight:

**Lemma 2:** In any value-maximizing equilibrium, \( d^B_t(\theta_t) = \pi^B_t(\theta_t) \) in each period \( t \) where the highest sustainable profit is smaller than \( \pi^M(\bar{\theta}) \), i.e. debt must be repaid as fast as possible.

*Proof:* See the Appendix.

Lemma 2 describes the optimal debt path as the fastest repayment path.\(^{11}\) The fastest repayment path provides for the highest debt service possible. For an intuition, consider the incentive constraint (2). The current debt service \( d_t \) enters both sides: A firm has to pay it whether it deviates or sticks to the collusive agreement. Therefore, any restriction on collusion depends only on the value of future debt payments, \( D_{t+1} \). Now if \( d_t \) can be increased then this allows to reduce \( D_{t+1} \) (from the lender’s break even condition), hence it increases the maximally sustainable level of collusion in all future periods.

On the fastest repayment path for bank debt, the debt level falls steadily. At some point, the remaining debt level must have fallen so low that collusion is no longer constrained. In other words, collusion can only be constrained in an initial phase.

This allows to take a closer look at the initial phase where collusion is constrained. Inspection of condition (2) shows that, whatever the current demand state \( \theta_t \), \( \pi^R_t(\theta_t) \) cannot

\(^{11}\)This term has been coined by Hart and Moore (1994), though in a somewhat different context.
surpass a certain threshold. I will denote this threshold profit by $\bar{\pi}_t^B$ (this threshold depends again only on time because $D_{t+1}$ is deterministic). $\bar{\pi}_t^B$ is determined by equality in equation (2):

$$
\bar{\pi}_t^B = \frac{1}{n-1} \left( \delta (V^B(D_{t+1}) - D_{t+1}) \right)
$$

This means that if $\pi^M(\theta_t) > \bar{\pi}_t^B$, i.e. if the current demand state $\theta_t$ permits a higher profit, then only a collusive profit of $\bar{\pi}_t^B$ is incentive-compatible; if $\theta_t$ is low i.e. $\pi^M(\theta) < \bar{\pi}_t^B$, then maximum collusion is sustainable. Thus, the value-maximizing path of profits is:

$$
\pi_t^B(\theta_t) = \min\{\pi^M(\theta_t), \bar{\pi}_t^B\}
$$

In other words, the maximal profit is initially a truncation of the distribution of maximal profits $\pi^M(\theta)$. The observation that debt falls steadily up to the level where it imposes no longer any restrictions is equivalent to saying that $\bar{\pi}_t^B$ grows over time until it hits $\pi^M(\bar{\theta})$ and collusion is not restricted any longer.

The important result of this section is that the fastest repayment path can indeed be attained as an equilibrium under bank finance:

**PROPOSITION 1**: (Banking equilibrium).

(i) Suppose all firms borrow from banks. Then the fastest repayment path can be sustained as an equilibrium.

(ii) A possible initial debt contract leading to this equilibrium has a debt service of $d_t^B = \bar{\pi}_t^B$ and a maturity of $T$ such that $I + M = \sum_{t=0}^T \delta^t E\pi_t^B(\theta_t)$. Actual debt repayments are successively reduced to the value-maximizing level $\pi_t^B(\theta_t)$.

Proof: See the Appendix.

Essentially, this result says that bank debt provides for as much flexibility in adjusting debt services as one might desire. Like in all repeated games, the equilibrium is not unique; in this case, not even the value-maximizing equilibrium is unique. In fact, any initial contract with debt services exceeding $\min\{\bar{\pi}_t^B, \pi^M(\theta_t)\}$, the upper bound of what could be repaid, could support the fastest repayment path.

The important part of this result is to verify the banks' incentives to renegotiate. This is not at all obvious because every dollar that a bank offers to forgive will directly reduce

\[^{12}\text{For high levels of debt, it is also possible that initially, collusion in all demand states is affected, i.e. } \bar{\pi}_t^B < \pi^M(\theta).\]
its payoff (it is through this renegotiation that bank debt becomes risky), and the banks seem to have all the bargaining power (they make take-it-or-leave-it offers). The reason why banks will offer these reductions nonetheless is as follows. Suppose a bank considers cutting back its current debt service to $d^B_t(\theta_t) = \pi^B_t(\theta_t)$, the debt payment on the value-maximizing path. If the bank makes this offer, bankruptcy is avoided. If the bank makes any less generous offer, bankruptcy will occur because the debt service exceeds the targeted profit. In this case, a possible continuation equilibrium is that the industry competitors respond by triggering to the punishment profile giving a zero continuation payoff. Most of the impact of this punishment in the industry will fall on the bank who will see no further repayment if the continuation profits are zero.

Thus, debt renegotiation is indirectly enforced by the industry competitors. The model explains a crucial role of third parties (industry competitors) in debt restructurings between a lender and a debtor. Collusion becomes in fact two-edged in the present model: Firms collude not only against their customers, but also against their lenders in order to extract the necessary debt adjustments.

This explains why the bargaining power between banks and firms is effectively reversed. As banks make a take-it-or-leave-it offer, they should in theory retain all the bargaining power. However, in this model, banks have actually quite a strong incentive to reduce debt payments, enforced by the threat that failure to reschedule leads to adoption of the punishment profile in the industry.

4. The public debt equilibrium

I turn in this section to publicly traded debt for which I use the superscript $D$. $V^D(D_t)$ denotes then the present value of the value-maximizing equilibrium with public debt, $d^D_t$ the optimal debt repayment in period $t$ and $\pi^D_t$ the maximum sustainable profit in $t$ under a public debt contract, i.e. $\pi^D_t$ is again recursively defined by the (binding) incentive constraint $\pi^D_t = \delta \frac{1}{n-1} (V^D(D_{t+1}) - D_{t+1})$, the equivalent of constraint (4). Finally, $\pi^D_t(\theta_t) = \min\{\pi^D_t, \pi^M(\theta_t)\}$ denotes the feasible value-maximizing profit, which is again either restricted by the current industry condition $\theta_t$ or by the remaining debt level $D_t$ and hence a truncation of the distribution of $\pi^M(\theta_t)$.

Consider then a situation where the remaining debt level $D_t$ is so high that $\pi^D_t < \pi^M(\theta)$, i.e. collusion is constrained. This creates in principle a motivation to pay down debt as fast as possible, as was the case with bank debt. However, there are poor states where
the firm defaults because the debt service is too high. Namely, if \( d_t^P > \pi_t^P(\theta_t) \) then the firm is not able to meet its debt obligations and bankruptcy occurs. There are then both good and bad contingencies where profits suffer compared to unconstrained joint profit maximization: For high realizations of \( \theta, \pi_t^P < \pi^M(\bar{\theta}) \) and profits must be capped to avoid deviation; for low realizations of \( \theta, d_t^P > \pi_t^P(\theta_t) \), and default is triggered. Both risks may occur concomitantly.

Thus, a clear trade-off emerges with respect to the optimal debt repayment path \( d_t^P \): On the one hand, paying down debt fast allows to lift the constraints on sustainable collusion more quickly. On the other hand, increasing debt services increase the risk of costly bankruptcy. The optimal repayment path has to strike a balance between these two forms of value losses.

A debt level of \( d_t^P \) will induce bankruptcy in \( t \) with probability \( F(\theta \mid \pi^M(\theta) < d_t^P) \). For convenience, I use the short notation \( F(d_t^P) \equiv F(\theta \mid \pi^M(\theta) < d_t^P) \) for the endogenous default probability. Given \( d_t^P \), expected bankruptcy costs are then \( F(d_t^P) E[\pi^M(\theta) \mid \pi^M(\theta) < d_t^P] \) which are endogenously determined by \( d_t^P \). The expected debt service in \( t \) is then

\[
Ed_t^P = (1 - F(d_t^P)) d_t^P
\]

On a competitive capital market, this default risk will be anticipated initially, and debt is priced for creditors to break even, \( I = \sum_{t=0}^{\infty} \delta^t (1 - F(d_t^P)) d_t^P \).

To characterize closer the typical repayment path, I add the following assumption concerning the bankruptcy costs:

**Assumption 4:** Bankruptcy costs are strictly convex in the expected debt service \( Ed_t^P \).

In essence, this condition guarantees that a smooth debt repayment path is preferred so as to minimize the endogenous bankruptcy costs. Implicitly, Assumption 4 imposes a mild restriction on the distribution function of maximal profits.\(^{13}\)

For the description of the optimal path with public debt, two important threshold levels for the debt \( D_t \) need to be defined. I consider the two forms of value losses separately, and I define \( D^U \) as the highest debt value where \( \pi^M(\bar{\theta}) \) is sustainable, i.e. \( D^U \) expresses the threshold debt level such that no losses accrue for realization of \( \theta \) at the upper end of the

\(^{13}\) For example, sufficient conditions for Assumption 4 are that \((1 - F(d))d\) is concave in \( d \) and moreover \( F(d) E[\pi^M(\theta) \mid \pi^M(\theta) < d] \) is convex in \( d \) for values of \( d \) below the debt capacity (see the next section). This is a mild condition satisfied by many distribution functions of maximal profits \( \pi^M(\theta) \), including the normal, the uniform and exponential distributions.
support. Likewise, I define $D^L$ as the highest debt value where bankruptcy and hence losses for realizations of $\theta$ at the lower end of the support can be avoided. Clearly, $D^L = \pi^M(\theta) \frac{1}{1-\delta}$ because $\pi^M(\theta)$ is the highest possible riskfree debt service. A priori, we cannot say whether $D^U > D^L$ or $D^U < D^L$, and therefore both cases are considered below. Obviously, debt imposes a barrier to collusion only if $I > \min\{D^U, D^L\}$.

I can then pin down the repayment path for public debt in the following way:

**Proposition 2:** Suppose Assumption 4 holds and collusion is initially constrained.

(i) There is a unique optimal repayment path where the debt level $D_t$ is either stationary or asymptotically falling to a stationary level.

(ii) If $D^U < D^L$, then collusion is only constrained during an initial phase.

(iii) If $D^U > D^L$, then there exists a threshold $I^S > D^U$ such that debt is stationary for all $I \leq I^S$. If $I > I^S$, then $D_t$ falls asymptotically to $I^S$ for a generic set of distribution functions and values of $I$.

**Proof:** See the Appendix.

The most interesting aspects are contained in part (iii), saying that the optimal path is stationary or exhibits convergence to a stationary debt level and implies that the constraints on collusion are permanent. Moreover, if $I > D^U$, i.e. if debt is initially so high that the highest collusive profit $\pi^M(\theta)$ is not incentive-compatible, then both types of value losses will persist forever: Bankruptcy in low demand states and a cap on sustainable profits in high demand states. This is in clear contrast to the results for bank debt where constraints on collusion are transitory.

Intuitively, the persistence of value losses along the equilibrium path is due to the fact that raising the debt services early on - the recipe used in the construction of the fastest repayment path - is now costly as it increases the bankruptcy risk. The debt service cannot be accelerated to the fastest repayment path: Bankruptcy would occur with certainty if such a high repayment was chosen. It may not even be optimal to reduce the debt level at all if that implies that the increased bankruptcy risk outweighs the benefits. This explains why for relatively low initial debt values ($I \leq I^S$), the optimal path will be stationary from the start: Any increase of the debt service would then cost more in terms of bankruptcy costs than it would yield in terms of a relaxed constraint on collusion.

In this perspective, the result in part (i) that the debt level cannot increase becomes interesting. The intuition for this is that even if reducing debt could save bankruptcy costs
initially, it would mean that the debt repayment needed just keeps the debt level in the future constant would have to rise. But such a path is dominated by a constant path because bankruptcy costs are convex.

Finally, if the debt level can be reduced without that bankruptcy costs are incurred (part (ii)), then the optimal time path seems to resemble the path with state-contingent debt as constraints are transitory. However, the debt repayment will be slower even in this case, as I confirm next.

5. Debt capacities and firm values

We are now in a position to compare the two debt alternatives and to derive expressions for firm values and debt capacities.

I will begin with a bank-financed industry. Recall that collusion is only constrained initially. I denote by $T^B$ the period of transition from constrained to unconstrained collusion. That is, the optimal repayment path follows the fastest repayment path until $T^B$ is reached and is indeterminate afterwards. $V^B$ then can be stated as:

$$V^B = E \sum_{t=0}^{T^B} \delta^t \pi^B_t(\theta_t, D_t) + \delta^{T^B} V^M$$

The debt capacity $D^B$ is the maximal amount of debt that a firm can take on initially without having incentives to deviate. To find $D^B$, one has to maximize the initial value of debt $D^B_0 = I + M$. At $T^B$, the remaining debt level $D_{TB}$ can be directly derived from incentive constraint (4) by imposing that collusion be unrestricted, $(n - 1)\pi^M(\bar{\theta}) = \delta(V^M - D)$, or:

$$D_{TB} = V^M - \frac{(n - 1)}{\delta} \pi^M(\bar{\theta})$$

$D^B$ can then be written as:

$$D^B = \max_{T^B} E \sum_{t=0}^{T^B} \delta^t \pi^B_t(\theta_t, D_t) + \delta^{T^B} \left( V^M - \frac{(n - 1)}{\delta} \pi^M(\bar{\theta}) \right)$$

In other words, to find the debt capacity, one needs to maximize $D_0$ with respect to $T^B$. $T^B$ is a monotone function of initial debt, and increasing $T^B$ extends the period for which all profits are paid to the bank, but reduces the initially sustainable profits. These tend to zero as $T^B$ goes to infinity. Thus, there must always be a finite maximizer $T^B$ of the debt capacity.
Next, I will turn to public debt industries. Let $D^D$ be the debt capacity with public debt. The calculation of $D^D$ must account for bankruptcy: Namely, the expected optimal debt service $Ed^D$ is first increasing in $d^D$ due to the rise in the debt repayment and then decreasing because the default risk is gaining the upper hand. In other words, the value of debt as a function of nominal future repayments exhibits a classical debt Laffer curve phenomenon. The maximum of the expected debt service $Ed^D$ is given by the first order condition of equation (6). This implies for the debt service in each period $d^D \leq \frac{1-F(d^D)}{f(d^D)}$ (and of course also $d^D < \pi^M(\theta)$).

Hence the first condition relevant for $D^D$ is given by the discounted value of the static debt revenue curve:

$$D^D \leq \max_{d^D} \frac{Ed^D}{1-\delta} = \frac{(1-F(d^D))^2}{f(d^D)(1-\delta)}.$$  

In addition, a second condition restricts the debt capacity which arises from the firms' incentive constraints. There must be a bound defined by sustainable collusion

$$D^D \leq \sup\{ D \mid \max\{\exists \pi^D(D) > D(1-\delta) \text{ s.t. } (n-1)\pi^D(D) \leq \delta(V^D(D) - D)\} \}$$

Thus, the debt capacity $D^D$ is determined by the minimum of the two constraints (10) and (11).

With these expressions, the comparison of the two alternatives is straightforward:

**Proposition 3:** Firms in a bank-financed industry have a higher debt capacity than firms in an identical publicly financed industry and will pay down their debt faster. Moreover, if $M$ is small enough then firms in a bank-financed industry have a higher initial value than firms in an identical publicly financed industry.

**Proof:** See the Appendix.

For an intuition of the value comparison, note that any level of initial debt will be paid down faster under bank debt. A faster pay-down of debt affects initial firm valuations positively. If in addition $M$, the monitoring cost that comes with private debt, is close enough to zero we are sure that bank debt is the dominant choice. For an intuition about the debt capacities and their relationship, take the debt repayment path of public debt. This path could be replicated under private debt without violating the incentive or any other constraint. But private debt can initially be repaid according to the fastest repayment path, while public debt cannot. It follows that for any given public debt repayment path, the initial debt with private debt can be higher.
6. Industry characteristics and the choice between private and public debt

In this Section, I will discuss how the choice between public and private credit can be explained by undertaking comparative statics exercises based on industry characteristics. I will discuss variations in the following parameters of the model: (i) The industry volatility; (ii) the concentration of the industry, as measured by the number of firms $n$; (iii) the market conduct; and finally (iv) the risk of permanent industry shocks.

6.1. Industry volatility

For the first comparative statics exercise, I look at increases in the demand volatility of the industry. I define an increase in demand volatility as a change in the distribution function of profits obtained by adding a random variable $\varepsilon$ with density function $g(\varepsilon)$ s.t. (i) $E \varepsilon = 0$ and (ii) $g(\varepsilon) > 0$ for all $\theta$ in $[\theta, \bar{\theta}]$. That is, increases in demand volatility are modelled following the well-known definition of an increase in risk (Rothschild and Stiglitz (1970)), i.e. by adding a pure noise while preserving the mean.$^{14}$

I find then that:

**Lemma 3:** The difference $V^B - V^D$ increases if demand volatility increases for values of $M$ small enough. The reversed case may occur for high values of $M$.

**Proof:** See the Appendix.

If bank financing is relatively cheap, then $V^B - V^D$ increases with demand uncertainty. The intuition is that an increase in demand uncertainty shifts probability mass towards the extreme points of the support of $\theta$. This can effect the attainable values with public debt on both ends of the support of $\theta$ because bankruptcy might be a possibility. It will affect public debt industries only at the upper end. Moreover, because private debt follows the fastest repayment path as long as collusion is constrained, it is less affected by the volatility increase: As long as $M$ is small, $\bar{\pi}_t^B > \bar{\pi}_t^D$ explaining that public debt will be more severely constrained by the volatility increase.

A potential countervailing effect arises from the fact that bank lending is more costly due to monitoring costs. If $M$ is large enough, then it may initially be the case that $\bar{\pi}_t^B < \bar{\pi}_t^D$, and the opposite effect may prevail: An increase in volatility penalizes bank debt more than public debt.

$^{14}$The definition stated here is slightly more demanding than Rothschild and Stiglitz (1970) as I require that the additional noise $\varepsilon$ is dense everywhere along $[\theta, \bar{\theta}]$. 

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6.2. Market concentration

The second industry parameter is *market concentration*, i.e. the number $n$ of firms in the industry. This is a straightforward exercise. I have assumed Bertrand competition, implying that the profits of a deviator are linearly increasing in the number of firms, $n$.\textsuperscript{15} Thus, the more fragmented the industry, the more is collusion constrained through debt. Next, I will argue that this will favor the use of bank debt if $n$ is relatively large.

The reason is directly related to the argument in the case of increasing demand volatility and a formal proof can therefore be omitted. Note that under Bertrand competition, the upper bound on collusive profits $\bar{\pi}^D_t$ and $\bar{\pi}^B_t$, respectively, is linearly decreasing in $n$. Therefore, the argument presented in the previous subsection directly carries over: Reducing this upper bound has the larger negative impact for public debt if $\bar{\pi}^D_t < \bar{\pi}^B_t$, and vice versa. For $M$ small, the upper bound must be more stringent for public debt financed firms. For $M$ high enough, a reversal may again occur and increasing the number of firms $n$ may favor public debt relative to private debt.

6.3. Market conduct

The third industry-specific comparative statics exercise is concerned with *market conduct*, i.e. the degree of competitive or collusive behavior in the industry.

So far, I have only considered the most collusive equilibrium where firms jointly maximize their profits. There are in fact many other Perfect Bayesian equilibria: Any payoff $\pi_t \in [0, \pi_i^*(\theta)]$ where $i \in \{B, D\}$ can be sustained as a Perfect Bayesian equilibrium. How is the choice affected if the industry equilibrium is in fact more competitive than the most collusive play?

The most collusive equilibrium is not necessarily the most plausible outcome. For example, industrial organization theory explains that factors other than those explicitly in the model influence the possibility to sustain collusive equilibria, like market transparency or production capacity. One could view market conduct being explained by these or similar factors.

I investigate this question by assuming that competition is strong enough to guarantee that a certain threshold $\bar{\pi} < \pi^M(\theta)$ of profits cannot be exceeded, even if the incentive constraint could be met. That is, firms will then choose profits $\hat{\pi}_i^*$ such that

\textsuperscript{15} Deviation profits will also increase in $n$ in a Cournot industry.
\[ \pi_i^* = \begin{cases} \pi_i^* & \text{if } \pi_i^* \leq \bar{\pi} \\ \bar{\pi} & \text{otherwise} \end{cases} \] (12)

I find then that:

**Lemma 4:** A decrease in collusiveness, i.e. a decrease in the maximal per firm profit \( \bar{\pi} \), leads to a decrease in the difference \( V^B - V^D \) for low \( M \).

**Proof:** See the Appendix.

The intuition for this finding relates to the constraints on sustainable collusion which we have defined as \( \bar{\pi}_i^B \) for bank debt and \( \bar{\pi}_i^D \) for public debt. The more competitive the market, i.e. the lower \( \bar{\pi} \), the more severely affects this bound the debt form for which the constraint is less stringent. If monitoring costs are low, this will be the case for bank debt.

### 6.4. Persistent industry shocks

The analysis so far was confined to an i.i.d. \( \theta_t \)-process. This is of course a simplifying assumption. In reality, the \( \theta_t \)-process would also have to reflect persistent industry slumps or booms.\(^{16}\)

As long as \( \theta_t \) was independently and identically distributed, it was optimal to adjust only the current debt service. This is no longer true if there are persistent shocks.

The following simple example can illustrate this. Suppose that immediately after contracting, a single permanent shock arrives which determines whether the industry is "rich" or "poor". All uncertainty is then resolved. Let \( \beta \in \{\beta_g, \beta_b\} \) denote this permanent shock, with \( \beta_g > \beta_b \) and both realizations occurring with equal probability. Let the state-contingent maximum debt level compatible with unconstrained collusion be \( D_g \) in case of state \( \beta_g \) and \( D_b \) in the state \( \beta_b \).

Because \( V^M(\beta_g) > V^M(\beta_b) \), it is easy to show that \( D_g > D_b \). With the assumption that

\[ D_b < I \leq \frac{D_g + D_b}{2} \]

we can quickly verify that there is a state-contingent debt level policy which dominates

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\(^{16}\)In the repeated games literature, extensions of the Rotemberg and Saloner model to encompass autocorrelated stochastic processes are discussed in Kandori (1991) and Bagwell and Staiger (1995).
a strategy where the debt level is only *time-dependent*. To see this, note that a time-dependent debt level must initially be at least as high as $I$ for investors to break even, implying that collusion is constrained in the bad state $\beta_b$ because $D_b < I$. But now suppose we start out with an initial debt level of $\hat{D} \leq D_g$, i.e. it leaves collusion unconstrained in the good state. This level is maintained in the good state $\beta_g$ and in the bad state renegotiated to a lower level of $D_b$. Assume that $\hat{D}$ is determined such that the bank breaks even, i.e.

$$\frac{1}{2} \hat{D} + \frac{1}{2} D_b = I$$

Obviously, with such a state-contingent debt policy, there is no constraint on collusion in either state.

The interesting question is of course whether such a downward adjustment in $D_t$ can be implemented through the mechanism of renegotiating bank debt described earlier. This is in fact possible. The debt reduction can be enforced by the following threat: Firms announce to play (unconstrained) joint profit maximization $\pi^M(\beta_b)$ in all future periods; if debt is not adjusted, they threaten to revert to the competitive outcome meaning a zero continuation payoff for the firms and for the banks, a Perfect Bayesian equilibrium of the continuation game. This insight is a very strong reminder of the strategic role played by third parties (industry competitors) in the debt renegotiation game between bank and debtor (Section 3).

In other words, if there are permanent shocks, then the optimal bank debt renegotiation policy implies that bank debt becomes substantially more risky. Reductions in the debt level $D_t$ are likely to be optimal, rather than only adjustments in the current debt service. This is in accordance with conventional wisdom: One would expect debt forgiveness to occur after persistent shocks and loan extensions (debt deferrals) after transient events. Of course, in any equilibrium of the full game, the condition that banks expect to break even must hold, for banks would not invest otherwise. This is the effective limit on the feasible reduction of debt and explains why collusion remains constrained if $I > \frac{D_g + D_b}{2}$.

With public debt, such an adjustment is impossible. This gives an intuition why one should expect the gulf between the continuation value $V^B(D_t)$ and $V^D(D_t)$ to widen if a permanent component is added to the $\theta_t$-process.

I will consider a parsimonious extension of the benchmark model so as to formally confirm this insight. I suppose that on top of the process $\theta$ of i.i.d. demand shocks, there is a multiplicative persistent industry shock $\beta$ which may occur in some period $T$. That is, the
permanent component $\beta \in \{\beta_b, \beta_g\}$, with $\beta_b < 1 < \beta_g$ is revealed in $T$, and in all periods after $T$, the maximal collusive profit depends on the product of $\beta$ and $\theta_t \pi^M = \pi^M(\beta \theta_t)$ for all $t > T$.

Because $\pi^M(\beta \theta_t)$ is monotonic in $\theta_t$, the permanent component $\beta$ will influence the firm value monotonically. But then the highest level of debt compatible with no restriction on collusion is also a monotonic function of the permanent component $\beta$-process. Therefore, it suffices to consider the optimal downward adjustment of the debt level in case the bad state $\beta_b$ arrives. By the same argument as before, there exists an equilibrium in this subgame where firms can force any level reduction to a new level upon their bank creditors.

I can then confirm the insight that this singular permanent shock biases the choice between the two debt alternatives in favor of bank debt:

**Lemma 5:** Consider a mean-preserving spread of the $\beta$-shock. Then the difference $V^B(D_t) - V^D(D_t)$ increases.

**Proof:** See the Appendix.

It is possible to extend this analysis to richer patterns of multiple or repeated permanent shocks.

### 6.5. The choice between private and public debt

The findings of this section can be summarized in the following form:

**Proposition 4:** Suppose that bank debt costs $M$ are sufficiently low. Then bank debt is optimal for firms in industries where:

- demand volatility is high
- industry shocks are persistent
- the market conduct is collusive
- the market concentration is low

and public debt otherwise. For high $M$, public debt is always preferred.

Proposition 4 contains the theory of the choice between public and private debt. It expresses a trade-off between state-contingency of debt and borrowing costs; the essential
element is that the value of the state-contingency of debt is explained by the market structure of the industry.

Previous work in industrial organization has shown that the more volatile is demand in an industry and the more a market is fragmented, the harder is it to sustain collusion. Proposition 4 adds the insight that the more important are these obstacles, the more will firms value state-contingent debt, given that the industry equilibrium which firms intend to play is indeed collusive rather than competitive. In other words, industry-specific characteristics could be an important determinant for the debt structure choice of a firm.

7. Collusion in the banking industry

So far, I have assumed that the market for bank loans is perfectly competitive, while industry firms could collude. In this Section, I discuss how a change in the competitiveness of the banking sector would influence the results. I capture the assumption that the banking market is imperfectly competitive by stipulating that banks can impose a higher costs of bank borrowing on their customers. I consider specifically the following simple change to the benchmark model:

**Assumption 5:** If banks collude, then they extract an additional premium from each borrower in proportion to the size of the initial loan. That is, if the banks lend initially \( I \), then the corresponding value of the debt is

\[
D_0 = I(1 + c) + M
\]

where the mark-up factor \( c > 0 \) measures the degree of bank collusion.

This extension fully represents a "smart" bank cartel for the following reason. Colluding banks try to extract as much surplus as their collective market power permits, which is measured by \( c \).\(^{17}\) A "smart" bank cartel would strive to maintain as much of the comparative advantage of bank debt as possible: It is in the collective interest of banks to allow their customers to achieve as high a value as possible, because the higher the profit per firm, the larger the fraction that the banks should be able to extract. If the bank cartel achieves to do this (and there is no reason that it should not as full debt renegotiation as

\(^{17}\)Standard reasoning in industrial organization shows that the market power of banks, captured here by \( c \), should increase e.g. in the market concentration and in the market transparency of the bank loan market.
in Proposition 1 can be enforced even with a bank monopolist) then the impact of bank collusion is limited to a higher cost of bank lending, as captured in the model extension.

In the analysis so far, I have looked only at firms which issued either 100% bank or 100% public debt. On a competitive market for loans, this simplification was in fact without loss of generality because once banks invested the set-up cost $M$, there was no further advantage of diversifying parts of the lending to other sources of credit. Once imperfect bank competition is allowed, this is no longer true. Therefore, I will now explicitly allow for mixed debt structures combining private and public debt, and characterize the optimal mix.

I can then allows the impact of bank collusion on the optimal combination of public and private debt as follows:

PROPOSITION 5: If $c > 0$, i.e. if there is imperfect competition in the banking industry, then firms will either use only public debt or a mixed debt structure combining public and private debt. The portion of public debt service in each period is at least $d^D_i \geq \min\{\pi^B_i, \pi^M(\theta_i)\}$.

The less competitive the banking industry (the higher $c$),
- the smaller the portion of debt financed through banks
- the smaller the fraction of industries where a mixed debt structure will be chosen.

Proof: See the Appendix.

Proposition 5 conveys two intuitive ideas. First, if the market for bank loans is imperfectly competitive, this hurts the position of bank lending relative to direct lending. This is so because the public capital market can always be tapped at competitive rates - the investors are atomistic and have no market power. In equilibrium, firms have a choice of borrowing from either an imperfectly competitive market or a perfectly competitive one, and the optimum moves in favor of the latter.

Therefore, collusion on financial markets and on product markets will influence the choice between private and public debt in opposite directions: Banks' importance in the financial system increases if product markets collude, but diminishes if financial markets are collusive.

\textsuperscript{18}It can be formally shown that in the limit as the number of investors goes to infinity, they cannot organize any degree of collusion.

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Second, imperfect bank competition gives rise to a quite natural interpretation of a division of labor on credit markets: In the optimal debt mix, the basis component is public debt providing credit up to the limit which can be safely guaranteed. To increase the debt capacity and the speed of repayment, this will be topped up by bank credit. In this view, the role of bank credit is one of providing the state-contingent component of debt. More precisely, starting from a fully bank-financed firm on the fastest repayment path, a certain fraction of bank debt can be substituted for public debt without any negative consequences: As long as the public debt service $d_t^D$ remains below $\min\{\overline{\pi}_t^B, \pi^M(\theta_t)\}$, the time-dependent lower bound of profits with private debt, renegotiation for that debt component is not needed.

8. Debt instruments: Callable debt and loan commitments

Before turning to a discussion of the empirical predictions, it is useful to look at some contractual options which are often used in practice and which can achieve state-contingency of debt, as an alternative or complement to using straight bank loans. I will briefly interpret two of them in the light of the findings.

Loan commitments and bridge loans. Short-term securitized debt instruments are frequently combined with loan commitments. State-contingent features of debt may also be obtained by using short-term instruments like bridge loans. This is consistent with the ideas exposed in the present model, and can be viewed as lending support to the idea that state-contingent components are added to the optimal debt mix.

Call provisions. Many corporate bond issues have call provisions. Interestingly, in the present model, there is a difference between debt renegotiation on the one hand and call features on the other hand.

Callable bonds incorporate state-contingency at the discretion of the manager, without a need to assure the consent of an outside investor like a bank. This explains the difference in attainable firm values. Under a call provision,

the initial contract would have to provide for a slower than expected repayment, and debt could be accelerated at the discretion of the borrower. I will argue that the fastest repayment path is not attainable. Namely, along the fastest repayment path, a firm would do better by not calling its debt and maximize its profit accordingly: Along the fastest repayment path, the incentive constraint is tight, so even without the call option, the firm is already indifferent between deviating and complying with the fastest repayment path. In
addition, by not calling its debt and deviating from the collusive play in the industry, the firm can keep the savings from the debt buy-back that was not executed, which gives it a higher total payoff. Thus, call provisions will sustain less collusion than debt renegotiation because a firm could always do better by deviating if the fastest repayment path were to supported by call provisions. Nonetheless, call provisions (or early redemptions for private debt) are a means of introducing some state-contingency of debt and they increase the firm value in the current model.

9. Summary of empirical implications

In this section, empirical implications are summarized and contrasted to existing evidence. The dynamic structure of the model allows to develop results along three lines: the dynamic evolution of the debt structure, industry determinants of the choice between bank and public debt, and product market effects of the debt structure choice. They relate to various research areas, including comparative financial systems, the cross-industry comparison of capital structure, as well as the dynamic financing mix of firms undergoing leveraged transactions.

I have so far maintained the assumption that all firms in the industry are identical. More heterogeneity across firms could be easily accommodated, including the case where firms within a single industry hold different debt structures or the case where firms have asymmetric market shares. From the argument presented in this paper, it is not hard to see that the firm with the least renegotiable debt structure to the most binding incentive constraint will then impose the effective constraint on industry collusion. Thus, it suffices to look at the firm which is critical for collusion.

An important caveat is to remind that there is a multiplicity of equilibria in this model, while for the most part I have looked only at the most collusive symmetric outcome. As argued in Section 6, however, less collusive equilibrium outcomes can be analyzed in the same framework, at the cost of a less accentuated difference between the two debt alternatives.

The following empirical predictions are original in the current paper:

**IMPLICATION 1:** Firms in industries characterized by (i) high earnings volatility

(ii) low market concentration (iii) a imperfectly competitive market conduct (iv) a larger risk of permanent industry slumps have a stronger incentive to prefer state-contingent debt in their financing mix.
There is empirical evidence demonstrating that firms in more volatile industries have a lower leverage ratio.\(^{19}\) Also, they tend to have shorter maturity (Stohs and Mauer (1996)). The present paper adds to this research the hypothesis that there should also be a relationship between the debt structure and demand volatility. Houston and James (1996), in their seminal study of mixed debt structures, present interesting evidence in this respect: For firms relying on public borrowing, bank credit is far from obsolete. A clue that this relationship might actually be found empirically is offered by Stohs and Mauer (1996) who show that firms in less volatile industries have higher credit ratings, and that firms with higher credit ratings use less state-contingent debt. I am not aware of any explicit test of these implications.

**Implication 2:** *The importance of bank lending is negatively correlated with the degree of competition on product markets and positively correlated with the degree of competition on credit markets.*

This inference helps to clarify the relationship between bank-centered financial systems, product markets collusion and financial markets collusion and should thus be viewed in the context of the theory on comparative financial systems. In Gerschenkron's remark quoted in the introduction have a high degree of collusion, it appears that collusion on both markets is mutually reinforcing. On closer inspection, however, this should not be the case: only product market collusion can explain bank-centered systems, not financial market collusion. This is consistent with evidence that bank-based financial systems may exhibit a considerable degree of banking competition.\(^{20}\)

**Implication 3:** *A monotonic relationship between leverage and competitiveness in an industry is less accentuated if debt is more state-contingent.*

The well-known prediction that leverage makes firms more willing to take bets against their competitors (Brander and Lewis (1986), Maksimovic (1988)) does not square well with the existing empirical evidence. Recent papers analyzing specific industries find that firms which increase their debt will reduce output, or fall in market share behind their competitors. Chevalier (1995) finds evidence in a study of the US retail industry. Phillips (1995) finds in three out of four industries that increased leverage will lower output. Kovenock and Phillips (1995) show that debt financing and product market

\(^{19}\)For example, Castanias (1983), Long and Malitz (1985), Titman and Wessels (1988) (not significant) or Sharpe (1994).

\(^{20}\)See Edwards and Fischer (1994) with respect to Germany.
competition are substitutes (and not complements) to achieve productivity gains in highly concentrated industries. The present model could help to fill the gap between theory and evidence: The state-contingency of debt matters. Unlike other arguments (Bolton and Scharfstein (1990), for example), this explanation does not require firms to have asymmetric capital structures.

**IMPLICATION 4:** Gradual de-leveraging is optimal for firms in collusive industries. The more state-contingent the debt structure, the faster should de-leveraging occur. State-contingent debt should be the more transient component, and public debt the more persistent component.

There is no comprehensive study of the behavior of industry leverage over time. Some clues can be collected from specific studies documenting the leveraged transactions activities in the US in the 80s. Blair and Schary (1991) document that these activities tended to cluster in certain industries and time periods making it an interesting study object for the ideas of to present paper. Evidence on LBOs suggests indeed that industry-leverage is not stationary. Kaplan (1991) shows that for publicly traded companies, debt is drastically reduced a few years after a LBO.\(^{21}\)

The rationale for the non-stationarity of the debt mix - more transient nature of state-contingent debt - is that in the model, state contingent debt is paid off faster. Along the efficient path, from time \(T^B\) on, there should be exclusively public debt. I am not aware of any explicit empirical study. Kaplan and Stein (1993) mention of their sample of LBOs from the 1980s that bank debt repayments are faster than the reduction of public debt and that the speed of bank debt repayments accelerated throughout the 1980s.

**IMPLICATION 5:** Firms in bank-financed industries should see more frequent adjustments of their debt repayments and firms in public debt industries have higher costs of bankruptcy. In industries where earnings volatility is more transitory, debt adjustments should take the form of debt deferrals and public debt is likely to exhibit the higher risk premium. In industries with more permanent earnings shocks, debt renegotiation is more in the form of debt level reductions and bank debt has the higher risk premium.

\(^{21}\)Another interesting evidence (though only indirectly connected to Implication 3): there are industry effects in leveraged transactions. Volatile industries with low leverage were those most exposed to leverage-increasing transactions (Seth (1993)).
There is some empirical evidence in support of Implication 5. Asquith, Gertner and Scharfstein (1994), in their analysis of troubled debt restructurings, find that banks are usually more reluctant to forgive principal, but more willing to extend credit, than public lenders. The higher cost of bankruptcy for public debt firms is documented e.g. in Gilson, John and Lang (1990) as well as many other studies.

**IMPLICATION 6:** Bank-financed firms in industries with volatile earnings have a higher debt capacity.

Debt capacity is difficult to put to a test, because debt capacities are hard to observe and it is unclear whether higher debt capacities translate, on average, in some form of higher mean debt levels. Unsurprisingly, I am not aware of empirical work pertinent to this implication.

**10. Conclusion**

In this paper, a gain in value of bank-financed firms is derived from the assumption that bank loans can be renegotiated ex post. In the repeated games setting, industry competitors assume a decisive role for the outcome of debt renegotiation. Bank debt permits a higher level of collusion because it can be repaid faster. Also, bank credit offers a higher debt capacity. Firms in industries where sustaining collusion is more fragile because of volatility or market fragmentation will prefer banks. Mixed debt structures are optimized so as to combine the cost advantage of publicly floated debt and the state-contingency of private debt, and they are dynamically rebalanced so as to support optimal de-leveraging.

There are many important questions that this paper does not address. For example, how do the findings of this paper compare to models with a shorter horizon and less accented reactions to deviations. Does the difference between private information production of banks and public information revelation of securities markets have an impact? The empirical implications are perhaps the most important open problems: to date, little empirical work interest has been devoted to the questions raised in this paper.
Appendix

Proof of Lemma 2: \((\theta_t, D_t)\) denotes the history-dependent state and \(d_t\) the control variable. Let \((d_{t+r}(\theta_{t+r}, D_{t+r}))_{r=0}^\infty\) be the optimal debt repayment path and \(\pi(d_t, \theta_t, D_t)\) be the maximally sustainable profit in period \(t\), which both are obtained from the recursive optimization. The Bellman equation can be written as:

\[
V_t(d_t, \theta_t, D_t) = \sum_{r=0}^\infty \pi(d_{t+r}, \theta_{t+r}, D_{t+r}) = \pi(d_t, \theta_t, D_t) + E_t \delta V_{t+1}(d_{t+1}, \theta_{t+1}, D_{t+1}) \quad (A.1)
\]

I will prove that increasing \(d_t(\cdot)\) up to the maximum feasible level \(\pi(d_t, \theta_t, D_t)\) always strictly increases \(V_t(d_t, \theta_t, D_t)\).

First, I show that increasing \(d_t(\cdot)\) does not reduce \(\pi(d_t, \theta_t, D_t)\) provided that \(D_{t+1}\) is unchanged. To see this, consult the incentive constraint written in the form:

\[
n \cdot \pi(d_t, \theta_t, D_t) - d_t \leq \pi(d_t, \theta_t, D_t) - d_t + E_t \sum_{r=1}^\infty \delta^r (\pi(d_{t+r}, \theta_{t+r}, D_{t+r}) - d_r) \quad (A.2)
\]

By definition of \(\pi(d_t, \theta_t, D_t)\), (A.2) must hold with equality. \(d_t\) appears on both sides and thus increasing \(d_t\) up to the feasible maximum leaves \(\pi(d_t, \theta_t, D_t)\) unchanged.

The accounting equation \(D_t = \sum_{r=0}^\infty \delta^r d_{t+r}\) implies that the remaining debt level \(D_{t+1}\) strictly decreases in \(d_t\). Next, I argue that \(E_t V_{t+1}(\cdot)\) must be strictly decreasing in \(D_{t+1}\) as long as collusion is constrained. From condition (A.2) it follows that \(\pi(d_t, \theta_t, D_t)\) increases strictly if the maximum sustainable profit increases in any future period without decreasing in any other. Now such a change in future profits can be achieved by the following rearrangement of the debt repayment path. Assume period \(s\) is the last period where collusion is constrained. Then increase \(d_t\) where \(t < s\); leave the debt service unchanged in all following periods from \(t + 1\) to \(s\) and decrease \(d_{s+1}\) by such an amount as to leave \(D_0\) unchanged. The incentive constraint in period \(s\) can then be written as:

\[
n \cdot \pi(d_s, \theta_s, D_s) - d_s \leq \pi(d_s, \theta_s, D_s) - d_s + \delta(V^M - D_{s+1}) \quad (A.3)
\]

Consider period \(s\). Because \(D_{s+1}\) has decreased, it follows that \(\pi(d_s, \theta_s, D_s)\) increases strictly and so do, by the recursive construction of the maximum profit, all previous profits \(\pi(d_t, \theta_t, D_t)\). Thus, \(E_t V_{t+1}(\cdot)\) strictly decreases in \(D_{t+1}\).

Proof of Lemma 1: The proof encompasses the public and the private debt case and therefore I suppress the subscripts \(B\) or \(D\).
Suppose we have solved recursively the optimal repayment path for two arbitrary levels of remaining debt $D^0$ and $D^1$, with $D^1 < D^0$. I denote the optimal debt services along the two optimal paths by $d_t^0$ and $d_t^1$. Concavity is established if whatever the levels of $D^0$ and $D^1$, for all $\alpha \in (0, 1)$ it is true that

$$V(\alpha D^0 + (1 - \alpha) D^1) > \alpha V(D^0) + (1 - \alpha) V(D^1) \quad (A.4)$$

Define for each $\alpha$ a path of debt values $(D_t^\alpha)$ which is the $\alpha$-weighted combination $D_t^0$ and $D_t^1$, hence $Ed_t^\alpha = \alpha Ed_t^0 + (1 - \alpha) Ed_t^1$ and $D_t^0 = \alpha D_t^0 + (1 - \alpha) D_t^1$.

I expand $V_t$ such that

$$V_t(D) = E[\pi(D_t)] + \delta E[\pi(D_{t+1})] + \delta^2 E[\pi(D_{t+2})] + ...$$

I will compare this expansion element by element, and show that $\forall \alpha$ and $\forall t$:

$$E[\pi(D_t^\alpha)] > \alpha E[\pi(D_t^0)] + (1 - \alpha) E[\pi(D_t^1)]$$ \quad (A.5)

I suppress time indices whenever possible and, for convenience, I denote by $\bar{\pi}(\alpha) \equiv \bar{\pi}(D_t^\alpha)$. (A.5) is

$$\alpha \left[ \int_{\bar{\pi}(D_0)}^{\pi M(\theta)} (\pi M(\theta) - \bar{\pi}(D^0)) f(\theta)d\theta + \int_{\bar{\pi}(\alpha)}^{\pi M(\bar{\pi})} (\pi M(D^0) - \bar{\pi}(D^0)) f(\theta)d\theta \right] - (1 - \alpha) \left[ \int_{\bar{\pi}(D_t^1)}^{\pi M(\theta)} (\pi M(\theta) - \bar{\pi}(\alpha)) f(\theta)d\theta + \int_{\bar{\pi}(D_t^1)}^{\pi M(D^1) - \bar{\pi}(\alpha)) f(\theta)d\theta \right] > 0 \quad (A.6)$$

This can be rewritten as:

$$\alpha \int_{\bar{\pi}(D_0)}^{\pi M(\theta)} (\pi M(\theta) - \bar{\pi}(D^0)) f(\theta)d\theta - (1 - \alpha) \int_{\pi M(\theta) - \bar{\pi}(D^0)}^{\pi M(\theta) - \bar{\pi}(D^0)) f(\theta)d\theta + \alpha \int_{\bar{\pi}(D_1)}^{\pi M(\theta) - \bar{\pi}(D^1)} (\pi M(D^1) - \bar{\pi}(D^1) - \bar{\pi}(\alpha)) f(\theta)d\theta > 0 \quad (A.7)$$

Recall that $\bar{\pi}_{t-1}(D_t)$ is a linear function of $V_t(D_t)$. It follows that if $V_t(D_t)$ is linear (concave) in $D_t$ then $\bar{\pi}_{t-1}(D_t)$ is linear (concave) in $D_t$. Applying this argument recursively shows that a sufficient condition to establish concavity of $V_t(D_t)$ in $D_t$ is to establish concavity if the following linearity assumption is imposed throughout:

$$\bar{\pi}(\alpha) = \alpha \bar{\pi}(D^0) + (1 - \alpha) \bar{\pi}(D^1) \quad (A.8)$$

Using the linear expression (A.8), the last two integrals of (A.7) can be rewritten as:
\[ \alpha \int_{\pi(D)}^{\pi(D')} (-1 - \alpha)\pi(D') - \alpha \pi(D^0) + \alpha \pi(D^0) + (1 - \alpha)\pi(D')) f(\theta)d\theta = 0. \]  
(A.9)

I rewrite the remaining expression as:

\[
\begin{align*}
&\alpha \int_{\pi(D')}^{\pi(D)} (\pi^M(\theta) - \pi(D^0)) f(\theta)d\theta - (1 - \alpha) \int_{\pi(D')}^{\pi(D')} (\pi^M(\theta) - \pi(\alpha)) f(\theta)d\theta \\
+ &\alpha \int_{\pi(D)}^{\pi(D')}(\pi(\alpha) - \pi(D^0)) f(\theta)d\theta \\
= &\alpha \int_{\pi(D')}^{\pi(D')} (\pi^M(\theta) - \pi(D^0)) f(\theta)d\theta - (1 - \alpha) \int_{\pi(D')}^{\pi(D)} (\pi^M(\theta) - \pi(D^0)) f(\theta)d\theta \\
+ &\alpha \int_{\pi(D)}^{\pi(D')} (\pi(D^1) - \pi^M(\theta)) f(\theta)d\theta.  
\end{align*}
\]  
(A.10)

This expression must be positive, as the last square bracket is positive.

**Proof of Proposition 1:**  
(i) and (ii) I discuss only a particular equilibrium supporting the fastest repayment path, based on the initial bank contract proposed in (ii). Consider firm \( n \) which has borrowed from bank \( k \). In any state of the game, characterized by \((\theta_i, D_i)\), consider the following stage game strategies: all firms other than \( n \) play a stage game profile according to \( \pi^B(\theta_i) \). Suppose \( \theta_i \) is realized, and consider the following actions. Bank \( k \) proposes to firm \( n \) a reduction of the current debt payment such that remaining total repayment in \( t \) adds just to \( \pi^B(\theta_i) \). (For example, claims could be deferred proportionally). That means, each single bank defers its claim in \( t \) in a “binding” way: offering just a little bit less means that the total payment due in \( t \) exceeds the critical mark of \( \pi^B(\theta_i) \). I show that neither firms nor banks will deviate. By definition of \( \pi^B(\cdot) \), we know that firm \( n \) will not deviate if this profile is adopted. Also, firm \( n \) will accept the offer because refusal would lead to bankruptcy and a continuation payoff of 0. Consider a deviation of bank \( k \). If \( k \) does not reduce its debt accordingly, then firm \( n \) will be bankrupt. Anticipating this, \( n \) will deviate in \( t \). There exists a PBE where \( n \) deviates whether this enables \( n \) to honor its period \( t \) payment or not and there exists a continuation equilibrium where \( \pi^p \) is triggered, giving a continuation value for each of the banks in the industry (including \( k \)) of be zero. Thus, bank \( k \) is induced to offer this debt reduction and the offer is accepted.

**Proof of Proposition 2:**

In each period, collusion could suffer because \( \pi^M(\theta_i) < d^D_i \) (bankruptcy) or because \( \pi^M(\theta_i) > \pi^D_i > d^D_i \) (constrained collusion). It is convenient to separate the value accounting of these two effects. This is possible as they are mutually exclusive. I call the discounted value of the value loss from the first effect (bankruptcy) \( L^B(D) \), and from the second effect (constrained collusion) \( L^c(D) \). Both are increasing functions of the remaining debt.
value $D$. The values of $L^b(D)$ and $L^c(D)$ are determined recursively. I can then write $V^D(D_0) = V^M - L^b(D) - L^c(D)$ and the optimal path is minimizes $L^b(D) + L^c(D)$.

(i) To prove this part, I show first that the optimal time path of the debt value must be monotonic or constant (Step 1) and then that it cannot be increasing (Steps 2 and 3).

Step 1: The optimal path of $V^D(D_t)$ and of $D_t$ must be monotonic or stationary in $t$.

$D_t$ is the control variable of a stationary dynamic optimization problem, and the value can be expressed as a function of $D_t$ alone. Stationarity implies that the value $V^D$ must be unique for each $D_t$. Optimality implies that $V^D(D_t)$ must be non-increasing in $D_t$ in the constrained area. Moreover, $V^D(D_t)$ is bounded above by $V^M$ and bounded below by zero.

I will next show that a situation where the control path $D_t$ describes some cycle within these boundaries as $t \rightarrow \infty$ cannot be part of an optimal path. To see this, let $t_1$ and $t_2$ denote two periods where $V^D(D_t)$ reaches its maximum within a cycle. Then $D_t$ must reach its minimum within at $t_1$ and $t_2$ which we denote by $D^m$. Let $d^m$ be the stationary debt service such that $D^m = \frac{E d^m}{1 - \delta}$. Then by the book-keeping equation of debt values, $\sum_{t_1}^{t_2} \delta^t E d^m = \sum_{t_1}^{t_2} \delta^t E d_t$ i.e. the expected debt payments are the same. The convexity of bankruptcy costs implies that the constant debt path $d^m$ induces lower bankruptcy costs. Finally, the firm value remains at the maximum in every period between $t_1$ and $t_2$ along the constant repayment path $d^m$, showing that cycles cannot be optimal.

Thus, the optimal path of $D_t$ and $V^D(D_t)$ must converge to a monotonic or stationary path. But then suppose that $V^D(D_t)$ follows a non-monotonic path initially. If $V^D(D_t)$ is first decreasing then increasing, the same proof as above shows that the process is not optimally controlled over every period where the firm value is in a local “valley”. If $V^D(D_t)$ is first increasing then decreasing, there must be a last period $t'$ where $V^D_t$ reaches a local maximum. But then there are periods after $t'$ where $D_t$ reaches a level which it has reached before. It must then be possible for $V^D(D_t)$ to rise again to the maximum it has attained in $t'$. This increases the value in $t'$, showing a contradiction.

Step 2: If $I < D^U$, a stationary path is optimal.

If $I < D^U$, then clearly $L^c = 0$ if the path is stationary. Note that the bankruptcy loss $L^b(D) = \sum_t \delta^t (1 - F(d_t)) E[\pi^M | \pi^M < d_t]$ is the sum of convex expressions in $D$ and hence also convex in $D$. It follows then that among all paths $(d_t)_{t=1}^\infty$ with the same present value of debt, a stationary path is the unique path minimizing $L^b$.

Step 3: If $I > D^U$, then the debt level must be non-increasing.
Consider a debt path \((\bar{d}_t)_{t=1}^\infty\) containing an increase in debt levels over some interval, starting from a debt level \(D_t\). Then compare this path to a stationary repayment path of \(Ed = D_t(1 - \delta)\). Compared to the stationary path, \((\bar{d}_t)_{t=1}^\infty\) is such that \(\bar{d}_t < d\) initially and \(\bar{d}_t > d\) later on, hence by the convexity of bankruptcy costs, \(L^b\) must be higher than on the stationary path. Moreover, because the debt level is increasing, \(L^c\) must also be higher. Hence \((\bar{d}_t)_{t=1}^\infty\) cannot be the optimal path.

Uniqueness of the path follows from the fact that \(V^D(D)\) is globally concave (Lemma 1) and convexity of bankruptcy costs, implying that the optimal control problem must have a unique solution.

\((ii)\) and \((iii)\)

**Step 1:** If \(D^U > D^L\), then there exists some \(I^S > D^U\) s.t. if \(I < I^S\), there exists an optimal path which is stationary throughout.

I first need to establish local properties of the function \(L^c(D)\) at the lower boundary \(D^U\): As \(D \searrow D^U\), \(L^c \rightarrow 0\) and \(\lim_{D \searrow D^U} \frac{L^c(D) - L^c(D^U)}{D - D^U} \rightarrow 0\) (\(L^c(D)\) is locally differentiable at the boundary).

As \(D \rightarrow D^U\), both the probability measure on these states \((1 - F(\bar{\pi}^D(D))) \rightarrow 0\) and the upper bound on the state-contingent value loss \(\pi^M(\theta) - \bar{\pi}^D(D) \rightarrow 0\). Hence the discounted sum of the expectation over \((1 - F(\bar{\pi}^D(D)))(\pi^M(\theta) - \bar{\pi}^D(D)) \rightarrow 0\).

Consider then \(I = D^U\). For this and lower levels of \(I\) in some neighborhood around \(D^U\), \(L^c = 0\) and \(L^b > 0\). Hence by convexity of \(L^b\), a constant path must be optimal. Next consider \(I'\) in some small neighborhood of \(D^U\), but \(I' > D^U\). By Step 3, the optimal path of \(D_t\) must be non-decreasing. Suppose \(D_t\) is decreasing. As \(I \rightarrow D^U\), we know from Step 1 that then \(\lim_{D \searrow D^U} \frac{L^c(D) - L^c(D^U)}{D - D^U} \rightarrow 0\). On the other hand, there is a cost form reducing debt compared to a stationary path, so \(L^b\) increases. Hence there must be a neighborhood of debt levels \(D\) around \(D^U\) where a stationary debt service is preferred.

**Step 2:** If \(D^L > D^U\), then \(I^S = D^U\).

Note that for \(I\) in some neighborhood around \(D^L\), \(L^b = 0\) and \(L^c > 0\). Hence increasing the current debt payment up to \(\pi^M(\theta)\) will always increase the value and the debt service must be at least \(\pi^M(\theta)\). Let \(d^U\) be the stationary debt service corresponding to a constant debt level of \(D^U\). \(D^L > D^U\) implies then that \(\pi^M(\theta) > d^U\), hence with a repayment path of \(\pi^M(\theta)\) or faster, debt is continuously declining. As soon as \(D^U\) is reached, the firm value is \(V^M\) and a stationary path is one of many optimal continuation paths.
Step 3: If $I \in (I^S, D^M)$ and $D^U > D^L$, then for generic distribution functions $F(\cdot)$ there is a unique optimal path. On this path, $D_t$ converges to a stationary path with debt level of $D^U$.

I will next establish the optimal debt service $d$ as an implicit function of $D$ which I call $d^*(D)$, and show that this function is increasing. From Lemma 1, $V^D(D)$ is strictly concave in $D$, as $V^D(D)$ is decreasing in $D$, the larger $D$, the steeper the negative slope of $V^D(D)$. Recall that an increase in $d_t$ increases the contemporaneous bankruptcy cost and decreases $D_{t-1}$ which in turn reduces $L^C(D)$ for all periods $\tau > t$. It follows that the shadow cost of reducing $d_t$ marginally strictly increases in $D$. Hence the optimal debt service $d_t$ must be an increasing function of $D$. This implicitly defines $d^*(D)$. A stationary equilibrium along the optimal repayment path can then be identified in $(d,D)$-space as a point where this upwards sloping function $d^*(D)$ and the straight line $d = D(1 - \delta)$ which defines all stationary repayment paths intersect.

Finally, for $I > I^S$ (but smaller than the maximum sustainable debt), the debt level is generically decreasing. Optimality of a stationary level requires a point in $(d,D)$-space where $d^*(D) = D(1 - \delta)$ coincide. These lines cannot intersect, however, as $d^*(D) < D(1 - \delta)$ is impossible. $(d^*(D) < D(1 - \delta)$ means that $D$, would have to increase in $t$, a contradiction to part (i) of this proof). Hence a stationary point must imply that $D(d,D)$ where $d^*(D)$ and $D(1 - \delta)$ are tangential. The shape of $d^*(D)$ depends on the two functions $L^C(D)$ (concave) and $E[\pi^M(\theta) | \pi^M(\theta) < d]$ (convex), and thus on the distribution function $F(\pi^M(\theta))$. $d^*(D)$ is generically non-linear. Therefore, within the class of all functions $F(\cdot)$ satisfying Assumption 4, the set of functions generating a dense set of such tangential points $I$ in the interval $I \in (I^S, D^M)$ must be non-generic.

Proof of Proposition 3: (i) Proof of $\overline{D}^D < \overline{D}^B$. Start with the optimal public debt contract. Suppose the capacity $\overline{D}^D$ and the associated optimal repayment path $d_t^D$ have been identified. I will show that there remains a possibility to add a small amount state-contingent debt, and yet the incentive constraints are satisfied. Note that $\exists t \geq 0$ such that $\overline{\pi}^D(D) > \pi^M(\theta)$ because otherwise the fastest repayment path would be possible with public debt for all periods $t$ leaving no surplus to the entrepreneur, a contradiction to constraint (2). Call $t^D \geq 0$ the first period where this is the case. This is the earliest possible period where state-contingent debt can be added. Next, I consider the following acceleration of debt: I add a small amount $\kappa$ of state-contingent debt to the debt service in $t^D$ and subtract a corresponding amount of debt some $K$ periods later in such a way that the initial debt $D_0$ is unchanged by this acceleration. Then this acceleration must entail
that a slightly higher level of collusion can be maintained between \( t^D \) and \( t^D + K \). Because maximally sustainable profits are a linear function of all future expected profits, it follows that maximally sustainable profits are up from the first period on. Next, I increase the debt service in \( t^D \) by another \( \varepsilon \). There must be a choice of \( \varepsilon > 0 \) such that sustainable profits between 0 and \( t^D \) are still at least as high as their levels under public debt with \( D^0 \). It follows that the incentive constraints are satisfied. Thus, at least an amount of \( \varepsilon \), with \( \varepsilon > 0 \), of debt can be added in \( t^D \) as a consequence of this acceleration. Hence by adding state-contingent debt, total debt can be increased beyond \( D^0 \), and hence \( D^B_0 > D^D_0 \).

(ii) Proof that \( V^B > V^D \) for small \( M \). Since \( V^B \) and \( V^D \) are strictly decreasing in \( D \), a sufficient condition is to show that in all periods \( t \leq T^B \) (where debt is still constrained under both debt alternatives): (a) \( d^B_t \geq d^D_t \) and (b) strict inequality in at least one period. (a) is immediate from the fact that \( d^B_t \) follows the fastest repayment path. To see (b), consider period \( T^B - 1 \). In this period, \( d^B_{T^B-1} = \pi^M(\theta_{T^B-1}) \); on the other hand, if \( d^D_{T^B-1} = \pi^M(\overline{\theta}) \), then bankruptcy will occur almost surely. Hence \( d^B_{T^B-1} < d^D_{T^B-1} \), showing the claim.

Proof of Lemma 3: Assume that \( M \) is close to zero. We know already that there exists \( T^B > 0 \) such that for the continuation values in \( T^B \), \( V^B = V^M > V^D \), i.e. collusion is only constrained with public debt. Define then the period \( \hat{T} \) as the period \( T^B \) after an increase in demand volatility. In period \( \hat{T} \), still \( V^B = V^M \) and \( V^D < V^M \). Moreover, the continuation value \( V^D(D^\hat{T}) \) is now in \( \hat{T} \) smaller than prior to the volatility increase (to see this, note that whether inefficiency arises for low values of \( \theta \) (bankruptcy) or for high ones or for both, the cumulative probability for these events has increased). Thus, in \( \hat{T} \), the difference \( V^B - V^D \) has increased. Next, I work backwards from this period \( \hat{T} \). In period \( \hat{T} - 1 \), the increase in demand volatility must imply a reduction in \( \pi^D_{\hat{T}-1} \) because \( 1 - F(\pi^D_{\hat{T}-1}) \) has increased and hence \( E\pi^D_t < E\pi^M \) has decreased. But the reduction in \( \pi^D_{\hat{T}-1} \) implies also a reduction in \( E\pi^D_{\hat{T}-1} \). Moreover, \( Ed^D_t = (1 - F(d^D))d^D \) is non increasing for all periods \( t < \hat{T} \) because the bankruptcy probability \( F(d^D) \) has increased. Next, I write the bound \( \pi^D_t \) for any period \( t < \hat{T} \) in the following way:

\[
\pi^D_t = \frac{1}{n-1} \left[ \delta(E\pi^D_{t+1} - Ed^D_{t+1}) + \delta^2(E\pi^D_{t+2} - Ed^D_{t+2}) + \ldots \right] \tag{A.11}
\]

On the other hand, with private debt we are on the fastest repayment path prior to \( t \), and the cap on profits can be written by combining expressions (4) and (8) as:

\[
\pi^B_t = \frac{1}{n-1} \delta^{t-1}(n-1)\pi^M(\overline{\theta}) \tag{A.12}
\]
Compare then (A.11) and (A.12). Each of the differences \((E \pi^D_{t+\tau} - E \pi^D_{t+\tau})\) in (A.11) for \(\tau \geq 0\) decreases as demand volatility increases, and also the difference \(V^B - V^D\) increases. On the other hand, the expression \(V^B(D_t)\) which determines \(\pi^B\) in expression (A.12) remains unchanged. It follows that the difference \(\pi^B_{t+\tau} - \pi^D_{t+\tau}\) increases with demand volatility, hence the difference \(E \pi^B_{t+\tau} - E \pi^D_{t+\tau}\). Because this holds for all \(t\) and \(\tau\), it must also mean that \(V^B(D_t) - V^D(D_t)\) increases.

Finally, I construct an example for the case for high values of \(M\). In this case, it is not necessarily the case that at \(\hat{T}\), \(V^B > V^D\). Suppose the opposite is the case. Because \(T^B\) increases with demand volatility, then the difference \(V^B - V^D\) will have decreased. If this effect is strong enough to outweigh the difference in the terms between \(t\) and \(\hat{T}\) in (A.11), then the reversal may occur.

Proof of Lemma 4: I can write the firm value as
\[
V^i = \sum_{t=0}^{\infty} \delta^t E \pi^i_t
\]
where \(E \pi^i_t\) is the expected firm profit if \(i \in \{B, D\}\) is the debt choice. If there is a cap \(\pi\) then \(E \pi^i_t\) is determined as the expectation of
\[
\pi^i_t(\theta, D_t) = \min\{\pi^M(\theta), \pi^i(D_t), \pi\}.
\]
Because we know that \(E \pi^B_t \geq \pi^D_t\) for all \(t\) if \(M\) is low enough (and strict inequality in some periods) it follows that a reduction in \(\pi\) will reduce the expectation \(E \pi^B_t\) at least as much as it reduces \(E \pi^D_t\) (and strictly more in some periods). Next, we proceed recursively. Assume \(t\) is the last period where a reduction in \(\pi\) reduces the difference \(E \pi^B_t - E \pi^D_t\). Hence the difference \(V^B(D_t) - V^D(D_t)\) has decreased. But recall that \(\pi^i_t\) is constructed recursively: if \(V^B(D_t) - V^D(D_t)\) is smaller, then \(\pi^B_{t-1} - \pi^D_{t-1}\) decreases, leading to a further reduction in the difference \(E \pi^B_{t-1} - E \pi^D_{t-1}\). Proceeding backwards proves the claim.

Proof of Lemma 5: Denote by \(p(\beta_9)\) and \(p(\beta_b)\) the probabilities of the two values of the permanent component. Take the debt level \(D^D_t\) as given and determine \(V^D(D_t)\). Then calculate for each pair \(\{\beta_b, \beta_9\}\) the continuation values \(V^B(D_t)\) for any level of \(D \in (0, D^B)\). The optimal state-contingent debt levels are the two levels \(D(\beta_9)\) and \(D(\beta_b)\) maximizing
\[
p(\beta_9)V^B(\beta_9, D(\beta_9)) + p(\beta_b)V^B(\beta_b, D(\beta_b))
\]
under the condition that
\[
p(\beta_9)D(\beta_9) + p(\beta_b)D(\beta_b) = D^D_t
\]
Next, the expectation $p(\beta_b)[V^B(\beta_b, D^D_0) - V^D(\beta_b, D^D_0)] + p(\beta_g)[V^B(\beta_g, D^D_0) - V^D(\beta_g, D^D_0)]$ must be non-decreasing in the mean-preserving spread: this is an immediate consequence of Lemma 3. Also, it is straightforward that the distance $D(\beta_g) - D(\beta_b)$ must be increasing in the mean-preserving spread. I can then conclude that

$$p(\beta_b)[V^B(\beta_b, D(\beta_b)) - V^D(\beta_b, D^D_0)] + p(\beta_g)[V^B(\beta_g, D(\beta_g)) - V^D(\beta_g, D^D_0)]$$

increases in the mean-preserving spread.

**Proof of Proposition 5:** For the first part of the Proposition, if $D_0^D = I$ is small enough to not restrict collusion, then public debt is always preferred. (At least) the fraction of debt that can be repaid without risk will be held as public debt because this reduces the total value of initial debt at no cost. This fraction is

$$\min\{\pi^B_t, \pi^M(\theta_t)\} > 0.$$  

For the comparative statics result, note that if bank debt is used, then the optimal debt structure has an interior solution and therefore expected bankruptcy costs (the marginal cost of using public debt) equals the marginal cost of bank debt, $1 + c$. Recall that the bankruptcy costs are strictly convex in public debt. Therefore, as $c$ rises, the marginal cost of bank debt increases, the optimal debt mix uses less public debt. Hence for a given $c$, there exists a choice of demand volatility such that an increase in $c$ will push the optimal debt mix beyond the boundary where only public debt becomes optimal.
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